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QUARTERLY REPORT

COLUMBIA RADIATION LABORATORY

July 30, 1954

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK
New York 27, N. Y.
Physics Department

QUARTERLY REPORT

COLUMBIA RADIATION LABORATORY

Report Number Seven
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(CRL Research in Progress)

(In this report the names of authors are arranged alphabetically.)

PUBLICATIONS

Sulfur Bonds and the Quadrupole Moments of O, S and Se Isotopes

G. R. Bird and C. H. Townes

Phys. Rev. 94, 1203 (1954)

Molecular Microwave Oscillator and New Hyperfine Structure in the Microwave Spectrum of NH_3

J. P. Gordon, H. J. Zeiger, and C. H. Townes

Phys. Rev. 95, 282 (1954)

SUMMARY

A. Magnetrons

Considerable success has been achieved in the design of a tunable magnetron at the 1 cm range. A tuning range of .15 cm at a mean wave length of about 1.25 cm has been achieved. The tube operates over the whole region and no discontinuities in operation are observed. Pseudo-cw tubes to operate at low magnetic field and a wave length of about 1.3 cm have been constructed.

B. Microwave Physics

Hyperfine structure of the NH_3 spectrum was measured in some detail with apparatus for the molecular beam oscillator and to an accuracy of about 1 kc/sec. The structure is explained theoretically except for minor discrepancies. The spectrum of tritium iodide was obtained near 2.4 mm wavelength and the mass of tritium thereby measured.

I. THE GENERATION OF HIGH FREQUENCIES

A. 22 Vane High Power Magnetrons at 6 mm (RPB7)

(M. J. Bernstein and N. M. Kroll)

During the past quarter effort has been devoted to the development of high temperature cathodes for the RPB7 tube and to the replacement of all glass parts of the tube with ceramic. Two new tubes have been constructed.

RPB7-26A - This tube utilized a moly-groove-oxide cathode and was provided with a ceramic window and ceramic cathode lead. No major difficulties were encountered in the fabrication of the cathode lead. The operation of the tube however was quite poor. A maximum efficiency of only 11% and a maximum power output of 65 kw was measured.

RPB7-27A - A pure molybdenum cathode which was heated by an internal uncoated tungsten coil was used in this tube. No test was obtained as it was not possible to obtain a high enough cathode temperature (~1700°C) to provide the necessary emission to start the tube.

The varied results obtained with ceramic output windows on these tubes indicate that more work will have to be done to improve the reproducibility of the output match. It is felt that the present output window is too sensitive to small changes in geometry.

A thoria cathode will be tried in RPB7-27A. This type of cathode should operate at a substantially lower temperature than the moly cathode previously used.

B. 22-Vane Magnetrons at 4.3 mm.(RPB8)

(M. J. Bernstein)

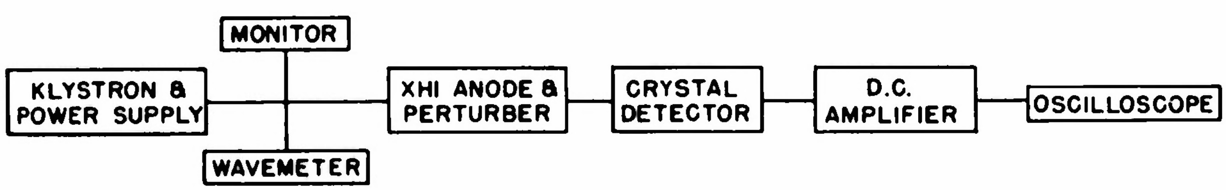
No new RPB8 tubes have been made during the past quarter.

C. Harmonic Generation in Magnetrons

(M. J. Bernstein, N. M. Kroll, and W. Strauss)

The pattern analyzer and associated electronic equipment have been assembled and a search for the mode spectrum of the XHl anode is in progress. The purpose of the mode search is to determine the wavelengths of the fundamental and harmonic mode spectra and to identify these modes. Of primary interest are the fundamental and harmonic π-modes since they are directly related to the operation of the proposed harmonic generator magnetron. In such a magnetron the anode must present a resonant circuit to a selected Fourier component of the space charge spokes. In order to achieve this integral relation between the frequency of the fundamental π-mode resonance and the frequency of the selected harmonic π-mode resonance of the anode it will be necessary to tune the harmonic π-mode. At the conclusion of the mode search, cold test on the XHl anode will be continued to investigate means of obtaining the necessary tuning.

A block diagram of the system is shown below.



The unit titled XHl and Perturber is shown in Fig. 1. It consists essentially of an input coupling loop and an output coupling loop, and a motor driven cathode to which a perturber is attached.

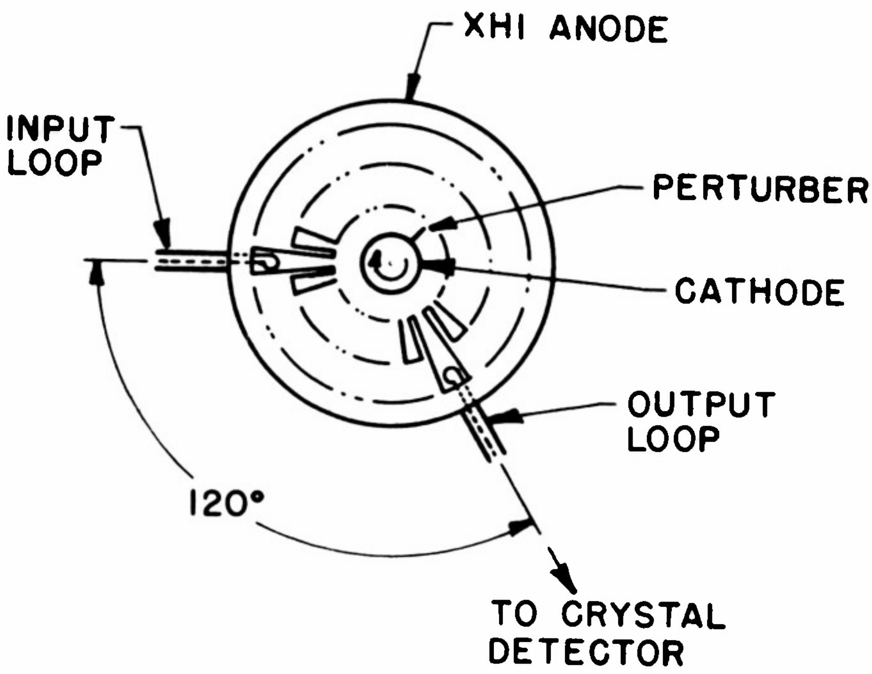


Figure 1

The perturbers used to date are constructed from 0.010 in. diameter nickel wire or 0.010 in. nickel sheets as shown below in Fig. 2.

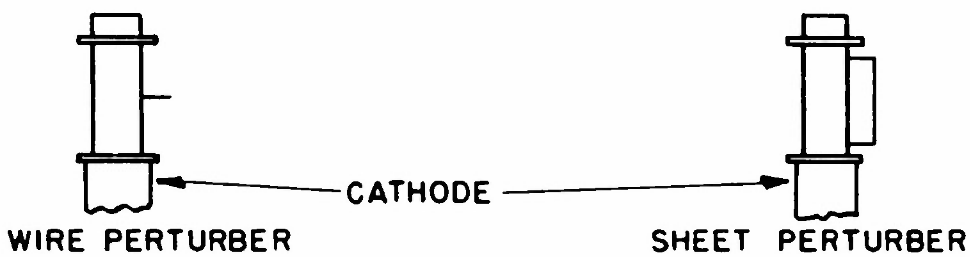


Figure 2

The radial dimension selected is governed by the strength of the coupling of the probe field with the interaction space.

Mode identification is accomplished as follows. After a resonance has been found, rf power at approximately the resonant frequency is fed into the XH1 anode via the input loop. As the

perturber rotates, variations in transmitted and reflected power as a function of perturber position can be observed. The transmitted power is viewed on the oscilloscope shown in the block diagram above; the variations in reflected power may be seen on an oscilloscope connected to the monitor. Photographs of transmitted and/or reflected power are taken and their interpretation leads to the identification of the mode under consideration.

The evidence available to date is not sufficient to warrant definite identification of modes in the frequency range covered. The foregoing remark does not apply to the π-mode. A preliminary identification is given below.

n	λ (cm)
1 ?	6.93
2	5.39
2	5.18
3	5.00
4	?
9 (π-mode)	3.46
8	3.17

Repeated attempts to locate the $n = 4$ mode with a single 2K44 klystron proved fruitless. When additional rf sources become available, the search will be repeated. In addition to the resonances tabulated above, the cavity responded at other frequencies. For example, a pattern of reflected power versus perturber position shown in Fig. 3, below, has been observed.

Figure 3

This pattern was traced from $\lambda = 4.82$ cm to $\lambda = 4.20$ cm in varying strengths. In order to observe this pattern the coupling of the input loop to the cavity and the radial dimensions of the perturber must be large. All the resonances of the long wave length multiplet listed above require only a weak coupling to the source of rf energy.

D. Crown of Thorns Tuning of Rising Sun Magnetrons

(M. J. Bernstein, N. M. Kroll, K. R. Rubin, and W. Strauss)

In order to understand more clearly the operation of the TRA1 tubes[1] with capacitive-pin tuning, a series of cold test measurements were made. TRA1-3, a duplicate of TRA1-2, was assembled and cold tested. It exhibited a tuning range from 1.19 cm to 1.39 cm. In addition a resonance was found which crossed the tuning curve at 1.29 cm. This is just the wave length where the efficiency of TRA1-2 dipped to zero. An attempt was made to remove the competing resonance. An end space filler ring was inserted in the cathode pole piece side as shown in Fig. 4.

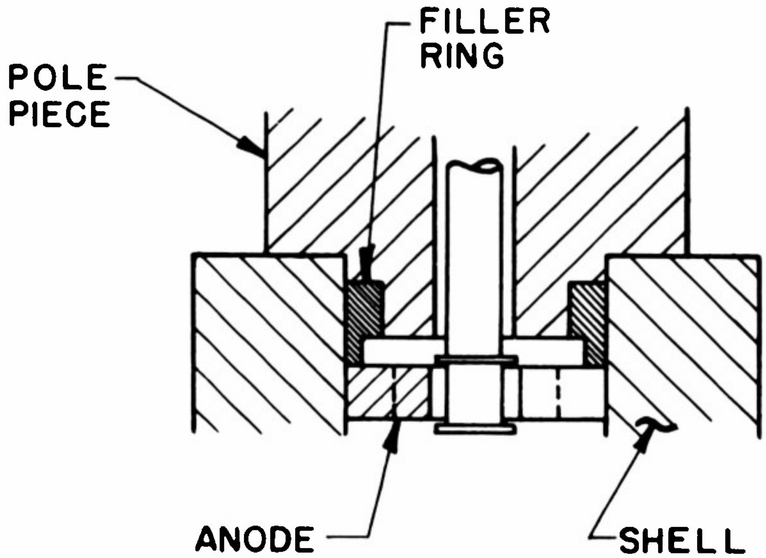


Figure 4

Cold tests on TRA1-3 modified in this way with a copper end space filler ring and with the pole pieces clamped into position, showed a tuning curve from 1.19 cm to 1.39 cm. A competing resonance was observed merging with the π-mode at 1.25 cm. When the tuning pole piece was brazed into position a slight shift in the tuning curve resulted but the competing resonance vanished.

TRA1-3 was also cold tested with an iron-glass end space filler ring. With the pole pieces clamped into position, no interfering resonance could be found over the tuning range.

On the basis of standing wave, "Q" and circuit efficiency measurements, TRA1-3 with the copper end space filler ring was completed and hot tested. The results are shown in Fig. 5. It is to be noted that the efficiency minimum has moved down to 1.21 cm and that it is no longer as deep as in the TRA1-2. It is hoped that by making use of two end space fillers, it may be possible to move the efficiency dip outside the useful tuning range.

TRA1-4 was constructed as a fixed frequency tube; it had a copper end space filler ring on the cathode side and standard pole pieces on both ends. This tube was build in order to ascertain whether the low efficiency of the TRA1-3 is assoctated with the tuning structure. The efficiency of the TRA1-4 proved to be about the same as that of the TRA1-3 and thus further tests are indicated.

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1. CRL Quarterly Report, April 30, 1954, p. 4.

E. Low Field Operation of Magnetrons

(A. H. Barrett, M. J. Bernstein, N. M. Kroll, and K. R. Rubin)

RV1 Series (20-Vane Tubes)

Another tube containing a tungsten coil cathode supported at both ends was constructed and tested (RV1-37W). The cathode diameter was .048 in. ($\sigma = .27$). Operation was quite similar to RV1-34.1 W with the difference that the magnetic field range was limited to 2210 - 2480 gauss. Peak operating voltage ranged from 4.4 to 5.0 kv. The maximum efficiency measured was 9.0% and the maximum output power was 18.3 watts. As in the case of No. 34.1 W, this tube was tested on unfiltered, full-wave rectified 60 cycle ac. Wavelength was 1.303 cm.

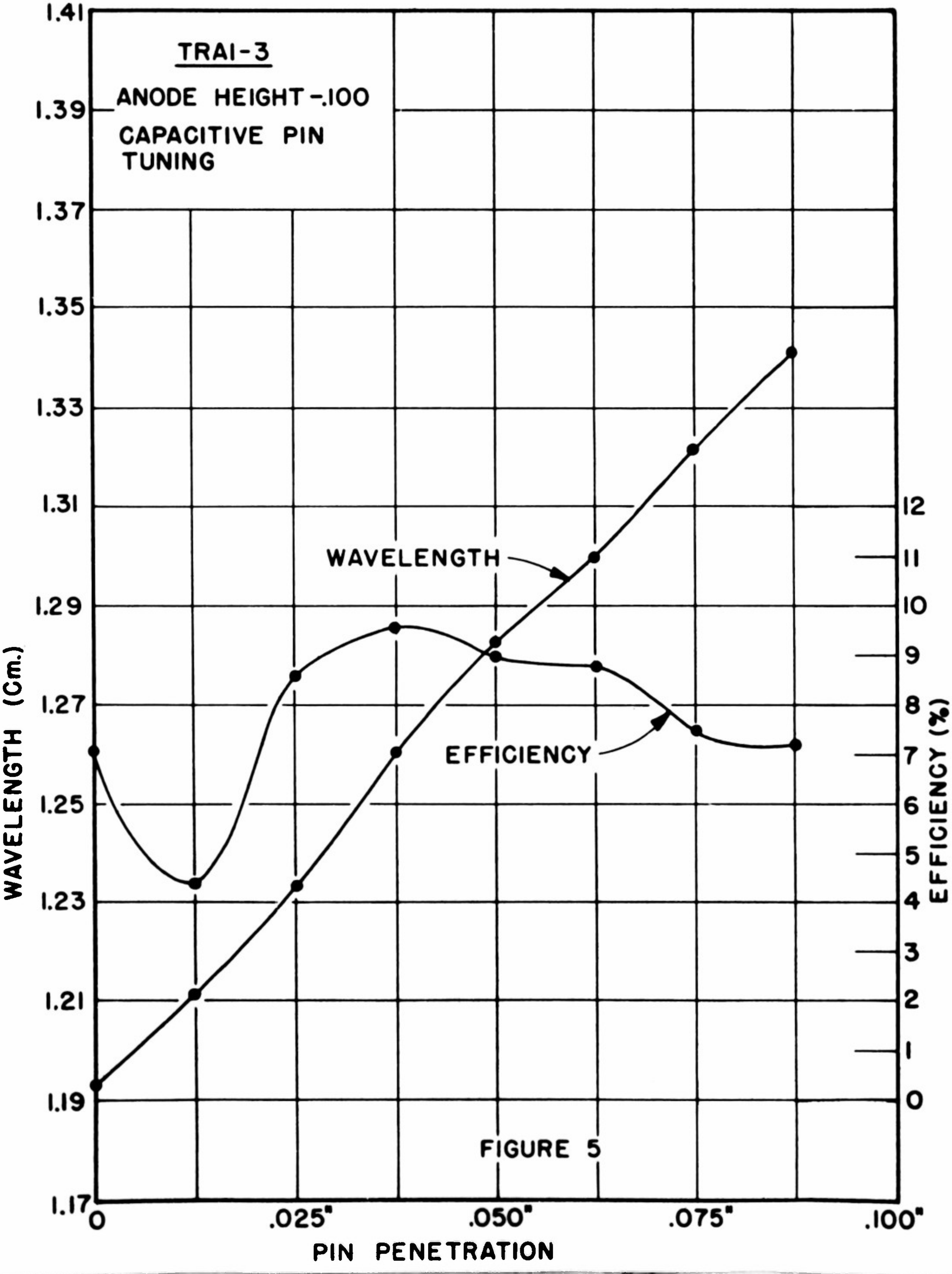
TRAI-3
ANODE HEIGHT -.100
CAPACITIVE PIN
TUNING
WAVELENGTH (Cm.)
1.41
1.39
1.37
1.35
1.33
1.31
1.29
1.27
1.25
1.23
1.21
1.19
1.17
EFFICIENCY (%)
12
11
10
9
8
7
6
5
4
3
2
1
0
WAVELENGTH
EFFICIENCY
0
.025"
.050"
.075"
.100"
PIN PENETRATION

FIGURE 5

Z1 Series (30-Vane Tubes)

Two 30-vane tubes with tungsten coil cathodes were constructed to determine whether operation under cw conditions was possible. The first of these tubes, Z1-7W, contained an .032 in. diameter cathode (σ = .12). Operation took place between 1120 gauss and 1660 gauss at voltages between 3.9 and 4.5 kv. Only a small amount of power ($\sim$ 1 watt) was observed over this region of operation. Wave length was 1.34 cm.

The second tube, Z1-8 W, contained a much larger cathode (D_c = .120 n, σ = .46). Operation, which was just as poor as No. 7 W, took place at much higher fields and voltages (1870 to 2500 gauss, 5.2 to 6.4 kv).

Further work on the cw properties of low field tubes will be confined to the 20-vane RV1 tubes. A lower voltage (Vo/2) 20-vane tube will also be designed.

RPB10 Series (22-Vane, 2.6 mm)

Three RPB10 tubes which are lower voltage versions of the RPB9 tubes have been built and tested during the past quarter. To date the results have not indicated any improvement over the RPB9 operation. All the tubes contained .027 in moly-groove-oxide cathodes (σ = .465) and were provided with cathode centering jigs.

RPB10-1 W

The wave length of this tube was measured as 2.60 mm. However only .5 kw at .4% efficiency was measured at 7.5 peak amperes and 18.0 kv at a magnetic field of 15,500 gauss. A moderate amount of arcing was observed during operation. Dis-assembly of the tube disclosed a badly eroded anode. Operation was above the Hartree line.

RPB10-2 W

No power output was obtained from this tube inasmuch as violent arcing persisted at all fields and voltages.

RPB10-3 W

Although no serious arcing occurred and anode currents as high as 10 peak amperes were obtained, no power output was observed from this tube. The tube was tested over the ranges of voltages from 11.0 to 18.0 kv at magnetic fields between 13,500 and 15,7000 gauss.

F. Generation of Millimeter Waves by Cerenkov Radiation

(M. Danos and H. Lashinsky)

The past quarter has been spent primarily in consideration of the design of the experimental arrangement discussed in the last Quarterly Report[1].

The calculations of the Cerenkov radiation have been completed for several additional cases: a flat beam sandwiched between two plane surfaces, a circularly cylindrical beam within a cylindrical hole and a single electron over a flat surface.

Difficulties with the wave guide vacuum windows have delayed the search for harmonics in the present apparatus.

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1. CRL Quarterly Report, April 30, 1954, p. 8.

G. Molecular Beam Oscillator

(J. P. Gordon and T. C. Wang)

A second molecular oscillator similar to the first is being built so that stability tests may be made by beating the two oscillators together.

Further experimental and theoretical work has been done on the magnetic hyperfine structure in the inversion spectrum of NH3, and a paper on these results is in preparation.

II. MICROWAVE APPARATUS AND TECHNIQUES

A. 6 mm Electronic Spectrum Analyzer

(A. H. Barrett and M. J. Bernstein)

Previous tests[1] have shown that a spectrum analyzer can be made to work satisfactorily at 6 mm by utilizing the second harmonic of K-band generated in the mixer crystal. As a result a new spectrum analyzer is being built which will permit the simultaneous operation of two klystrons, a local oscillator and a frequency marker klystron. The power supplies of this analyzer will allow the operation of available klystrons in the wavelength range of 8-17 mm. Thus, by using the second harmonic, the range from 4-17 mm will be made available for viewing magnetron spectra.

At the present time, the receiver, control panel, and low voltage power supply have been completed. A Dumont oscilloscope has been modified to provide the klystron sweep voltage. Power supplies for the klystrons are being constructed.

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1. CRL Quarterly Report, January 30, 1954, p. 7.

B. Crystal Harmonic Generators and Detectors

(W. R. Bennett, A. H. Nethercot, Jr., and B. Rosenblum)

Some quantitative data have been taken with detectors at 6 mm on the effect of an increase in pressure of the whisker on the silicon.

The pressure was gradually increased by advancing the base of the whisker with a differential screw mechanism. Five different whiskers were studied and they all showed the two voltage maxima at 1 mil and 5 mil spring deflections indicated in Figure 6. In four cases the first voltage maximum was the larger as shown; in the fifth instance the second maximum was the greater.

The behavior of the rectified current showed more variability than the voltage, but in all cases except one the 5 mil current peak was the greater. Since signal-to-noise ratio is the important quantity in a detector, and this is proportional to $\sqrt{IV}$, the curves show that in all cases except one, the 5 mil spring deflection is the more favorable by a rather large factor.

This same type of behavior was previously noticed at higher harmonics (7th and 8th), namely that two spring deflections gave approximately the same voltage signal and that the second was considerably less noisy. The second position was also more stable.

It might also be mentioned that for individual detectors while the current and voltage peaks at 1 mil have their maxima at the same position, the current peaks at 4.5 mils may be displaced up to ± 2 mils from the voltage peaks.

The VSWR remained fairly constant over the range of deflections investigated. With three of the whiskers it remained constant at 2 or 3 and on another it gradually changed from 1.7 to 3.5 and then back to 2.9. It was also found that the best position of the shorting plunger remained constant as the pressure was increased. The video resistance of the crystals begins at 100,000 to 300,000 ohms, decreases at the second peak to 20,000 to 100,000 ohms, and then usually increases again.

Harmonic generators behave very similarly to detectors as the contact pressured is changed.[1] For the former, best behavior was obtained at deflections of about 0 mils and 6 mils with the 6 mil position being the more stable, less liable to burnout, and less sensitive to the adjustment of the fundamental power.

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1. CRL Quarterly Report, April 30, 1954, p. 13.

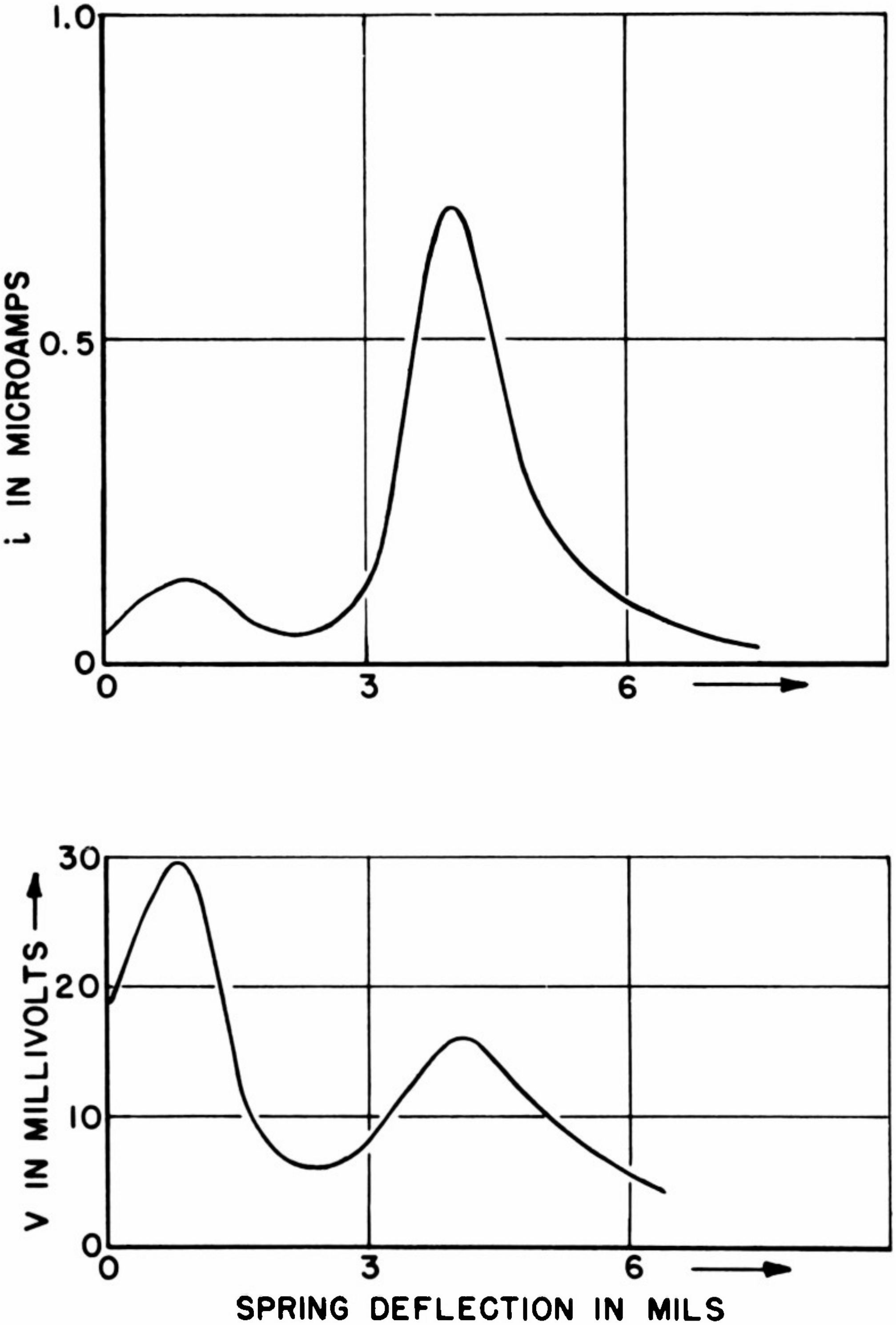

FIGURE 6

Composite Curves of Crystal Detection Rectified Current and Voltage Versus Whisker Detector.

III TUBE FABRICATION TECHNIQUES

Hob Grinding and Hot Hobbing

(M. J. Bernstein and C. O. Dechert)

No new hobs have been completed during the past quarter.

IV. MICROWAVE PHYSICS

A. Hyperfine Structure of the Hydrogen Atom

(J. Herberle, P. Kusch, and H. Reich)

1. Rf System

During the run of March 28, 1954 it was found that the available rf power in the previously constructed generator was insufficient to give an optimum flop. Difficulty was also experienced with the frequency-measuring apparatus.

Accordingly a two-stage rf power amplifier was constructed. It is driven by a tunable oscillator (General Radio Co., type 757-A) and is capable of delivering 70 watts at 177 Mc/sec. The frequency-measuring apparatus has been improved so that frequencies can be measured to one part in 10^7.

2. Run of June 5, 1954

After the improvements indicated above were made a new attempt was made to observe the Ramsey interference. The two rf floppers were driven in phase. Contrary to expectations a minimum in the curve which relates the fractional flop, Q, to the frequency was observed at the center of the 2-4 resonance (the field-independent line) $F = 1,\ m = 0 \leftrightarrow F = 0,\ m = 0$.

The explanation of this observation is that the magnetic field in the first rf flopper is opposite in sense from that at the second rf flopper. This means that there is phase difference of 180° between the matrix elements which govern the magnitude of φ.

As explained by Ramsey and Silsbee[1], the percentage flop at the center of the resonance will be at a minimum under these conditions.

It was found that the stray magnetic field from the polarizer was much too large at the first rf flopper, and in the wrong direction at that.

3. New Polarizer and Exciter

A new polarizer and exciter were constructed during the past quarter. Extensive measurements of the stray magnetic field from the polarizer were made by means of the rotating flip coil described earlier[2].

By trying out various configurations of iron for the magnetic circuit of the polarizer a design was evolved which reduced the stray field at the first rf flopper to a few centigauss.

Various improvements have been incorporated in the design of the new exciter. The principal improvement is a longer filament which will have a longer emitting region.

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1. Ramsey and Silsbee, Phys. Rev. 84, 506, (1951)
2. CRL Quarterly Report, December 31, 1952, p. 22.

B. Fine Structure of Singly Ionized Helium

(N. Kroll, E. Lipworth, M. McDermott and R. Novick)

During the past quarter the mercury pumps have been activated for the first time. Ultimate vacuums of 5×10^{-7} mm Hg in the main system and approx 10^{-6} mm Hg in the multiplier systems have been obtained.

In order to examine whether the new system is an improvement over the old as far as cleanliness is concerned two contamination tests have been made. The electron gun was installed in the apparatus and run for several hours under the following operating conditions:

Magnetic field	=	16,000 gauss
Bombarding Voltage	=	200 volts
Bombarding Current	=	.65 Ma

Here the average bombarding current is about ten times greater than that which was used in the earlier form of the experiment, when electron induced contamination was a serious problem. The running times for the two tests were 50 and 40 hours respectively.

The results of both tests indicated that some source of contamination remains in the apparatus but that its magnitude is small. In both cases the collector was discolored by a black deposit that conformed to the outlines of the filament. The deposit was not at all thick and disappeared when the collector was heated in hydrogen. Similar but much thicker deposits obtained with the old apparatus did not disappear when heated in hydrogen. The nature of the deposit is not known.

The vacuum envelope is constructed with iron inserts that continue the electromagnet pole tips into the vacuum. In order to prevent any possible adverse charging effect that may take place upon the exposed iron surfaces (and in the interest of general cleanliness) the interior of the vacuum envelope has been gold plated.

A preliminary test has been made of the electronic counting system. Despite the fact that the Allen Tube detector has been exposed to air since October of 1953 it worked as well as it ever did.

A lithium nuclear resonance detector and a rotating flip coil probe have been constructed to measure the magnetic field, Difficulty has been experienced in obtaining a sizeable lithium resonance, perhaps due to the small sample volume that we are forced to use because of limitations of space.

The rotating flip coil consists of a 30 c/sec synchronous motor that carries two coils upon a shaft. One coil rotates in the unknown field, the other in a fixed comparison field. The coil outputs are mixed in a bridge circuit. Balance is detected by presenting the

bridge output, taken through a high gain narrow band 30 c/sec amplifier, upon an oscilloscope. The sensitivity is such that a change in field of 1 part in 50,000 can easily be detected and measured. The magnet regulator presently in use appears to hold the field stable to better than a part in 100,000 for short periods of time[1].

A pulser designed to impose square wave modulation upon the klystrons is almost complete. The modulation frequency is to be 1 Kc rather than the 10 Kc proposed earlier[2]. Provision has been made to oil-cool the klystron when in operation.

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1. CRL Quarterly Report, April 30, 1954, p. 18.
2. CRL Quarterly Report, April 30, 1954, p. 19.

C. Nuclear Quadrupole Resonant Lines

(T. C. Wang)

From previous measurements of hyperfine structures[1] in microwave absorption spectroscopy, the quadrupole coupling constant eQq of Cl^{35} in chloro-germane is known to be about 46 Mc. Since Cl^{35} possesses a spin of 3/2, the frequency of pure nuclear quadrupole resonance of Cl^{35} in chloro-germane should be about 23 Mc. Seven runs have been made to investigate the pure quadrupole resonance of chlorine in solid chloro-germane. No signal was found in the frequency range 12 - 25 Mc. The reason for the absence of this signal is not presently known.

---

1. P. Kisliuk and C. H. Townes, Molecular Microwave Spectra Tables, National Bureau of Standards Circular 518, p. 69 (1952)

D. Very High Temperature Microwave Spectroscopy

(A. H. Barrett and M. Mandel)

During the past quarter an unsuccessful attempt was made to observe the absorption spectra of TlCl[1]. A search was made in the frequency range 19,180 to 21,160 Mc and 25,960 Mc to 26,600 Mc at temperatures varying between 300°C and 440°C.

A second attempt to observe lines of AgI and AgCl again met with no success.

A run was attempted with CuI, and several lines were measured with a wave meter. The sample residue of this run consisted of a mixture of fine magnetic black power and shiny metallic fragments which apparently were free copper. The lines could not be reproduced in any further runs on CuI. The sample residues in these latter runs showed no trace of free copper.

The next molecule studied was PbS whose B_e value is known from infrared work[2]. An extensive search failed to yield lines of PbS; however ten lines, nine of which were identified as SO_2 lines[3] were found. One line at 23,211 Mc (wave meter reading) was not listed as a known SO_2 line but it could perhaps arise in a high vibrational state of SO_2 excited by the high temperature of the sample (700°C).

The residue remaining in the sample holder after the PbS runs was, in most cases, slightly magnetic. Further tests indicated a reaction, under vacuum and at high temperatures (550-700°C), between PbS and nickel, of which our guide is composed.

It is intended to make a study of the rare earth halides. Since a typical absorption coefficient of the order of 10^{-8} cm^{-1} characterizes these symmetric top molecules, we have spent considerable time in improving the sensitivity of the apparatus. The main changes that have been made are:

1. The receiver has been retuned.
2. All carbon resistors in the first stage of the receiver have been changed to wire wound resistors.
3. A low-noise pre-amplifier has been installed.
4. The microwave paths have been shortened and all choke joints eliminated.

The above changes have resulted in a decrease in the minimum detectable absorption coefficient from 10^{-7} cm^{-1} to 5×10^{-9} cm^{-1}.

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1. R. O. Carlson, C. H. Lee, and B. P. Fabricand, Physical Review 85, 784 (1952).
2. H. Bell and A. Harvey, Proc. Phys. Soc. London 50, 427 (1938).
3. Molecular Microwave Spectra Tables, Kisliuk and Townes.

E. Free Radical Experiment

(G. C. Dousmanis)

The assembly of the Stark spectrometer with the aluminum cell[1] has been completed. A steady biasing voltage in excess of 1600 v and a sinusoidal 228 kc voltage of 1500 v rms can be applied between the septum and the guide without any breakdown of the insulation.

The sensitivity of this spectrometer is mediocre. The $J = 5_{23} \rightarrow 6_{16}$ water vapor line at K-band (intensity = 9.6×10^{-6} cm^{-1}) appears with a signal to noise ratio of 200:1. This line can be also seen when the rf discharge, used to produce the OH, is applied to the H_2O vapor before it is admitted to the cell; the signal to noise ratio is in this case 100:1. In repeated attempts, we have been unable, so far, to observe the OH spectrum with this instrument. A serious difficulty encountered in these runs is that the discharge shows a tendency, exceptionally strong at high Stark voltage, to "jump" inside the absorption cell, when the red color of the discharge changes to blue. The bluish color shows the presence in the gas of some organic compound the source of which must be the teflon insulation that is presumably broken down when the discharge jumps inside the cell. The evolved gas would eliminate the OH. As a result of these breakdowns the septum has shorted. The system will be taken apart for repair and modifications.

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1. CRL Quarterly Report, April 30, 1952, p. 22.

F. Polymeric Content of Alkali Halide Beams

(R. C. Miller)

During the past quarter, the experimental phase of the project has been completed. Significant data have been obtained on the following alkali halides: cesium chloride and bromide, rubidium chloride, potassium chloride and iodide, sodium flouride, chloride and iodide, and lithium chloride and bromide. In the last Quarterly Report, it was stated that further work was to be done on rubidium iodide. However, since previous data on rubidium iodide indicated no anomolous behavior, it was decided to investigate rubidium chloride as a representative rubidium halide, thus completing the alkali chloride series.

It has been previously reported that cesium chloride and cesium bromide beams were found to be essentially monomeric. Final calculations are currently being carried out on the remaining compounds. Except in the case of lithium halides, the results indicate that the experimental velocity distribution can be accounted for by assuming that the beam consists of monomers, and dimers. Careful investigation of the lithium halide distributions has shown that about 5 percent trimer is required to account for the distribution. All other beams consisting of three components, such as monomers, dimers and quadrimers or monomers, dimers and atomic lithium can be excluded as they do not produce a reasonable approximation to the experimental cruve. It is conceivable that the beam may consist of the four components, monomers, dimers, trimers, and quadrimers, but the method lacks the sensitivity required to deal with a system of the degree of complexity.

The dissociation energies will be calculated for the dimers of rubidium chloride, potassium chloride and iodide and sodium flouride, chloride and iodide. In the case of the lithium halides, the complexity of the possible reactions precludes a determination of dissociation energies. The dissociation energy of $(LiCl)_2$ quoted in the last Quarterly Report was calculated assuming only the existence of monomers and dimers.

The present plans of the laboratory do not include a continuation of this work. In completing the research it is planned to write two papers to describe completely the work which has been done. The first paper will cover the work in the velocity distributions in atomic beams of potassium and thallium. The second paper will cover the investigations on alkali halide beams.

G. Millimeter Wave Spectroscopy

(A. H. Nethercot, Jr. and B. Rosenblum)

The microwave spectrum of tritium iodide has been observed at the fifth harmonic of a 2K33 klystron using a harmonic generator. The observed frequencies were 131,592.95 $\pm$ .25 Mc for the $J = 0 \rightarrow 1$, $F = 5/2 \rightarrow 7/2$ transition and 131,210.20 $\pm$ .40 Mc for the $F = 5/2 \rightarrow 5/2$ transition. These frequencies are in excellent agreement with the frequencies predicted from the microwave values of B_0 and eqQ for DI[1,2] and the infrared value of α for HI (corrected for TI to α = 1016 $\pm$ 3 Mc)[3]. The predicted value of ν_0 is 131,501.6 Mc and the measured value 131,501.85 $\pm$ .40 Mc. The measured eqQ is 1822.6 $\pm$ 3 Mc.

The mass ratio of tritium to deuterium is obtained from the equilibrium B values and is 1.497458 $\pm 4 \times 10^{-6}$. Only 1×10^{-6} in the error is due to the error in α since the error in α occurs almost equally in the numerator and denominator. From the known mass of deuterium (2.014735 $\pm 6 \times 10^{-6}$ a.m.u.), the mass of tritium is calculated to be 3.016983 $\pm 12 \times 10^{-6}$. The mass from nuclear reaction data [4] is 3.016997 $\pm 11 \times 10^{-6}$, which differs by only 14×10^{-6} a.m.u.

This good agreement seems to be fortuitous when various electronic effects are considered. In order to obtain an idea of their order of magnitude, if one extranuclear electron were taken from the tritium and the deuterium in their respective molecules, the measured tritium mass would be 240×10^{-6} a.m.u. too heavy.

Actually the ionic character of HI is only about 5%, and in both isotopic molecules about 1/20 of an electron is taken away from the hydrogen isotope. This would make the microwave value of the tritium mass 12×10^{-6} a.m.u. too heavy. The slipping of the spherically symmetric part of the valence electrons would have a further tendency to make the tritium mass too heavy, but this effect is difficult to estimate accurately. The p-hybridization of the predominantly s-type hydrogen atomic orbital would be in the opposite direction, but the effect would be small.

The most important effect would be the L-uncoupling.[5] This is the excitation of higher electronic molecular states by

the rotation of the molecule. It effectively makes the molecule heavier. The fractional error in the mass ratio (δ) is given by:

$$\delta \approx \frac{(\nu_0' - \nu_0'')L(L+1)}{2J(W_\pi - W_\Sigma)}$$

if the pure precession hypothesis is used.

For DI where $W_\pi - W_\Sigma \cong 60,000 \text{ cm}^{-1}$, $L = 1$, $\nu_0^{DI} - \nu_0^{TI} \cong 2 \text{ cm}^{-1}$ and $J = 1$, this amounts to an error in the mass ratio of 30 parts in 10^6 and makes the mass of tritium 90×10^{-6} a.m.u. too light.

Taking into account all these electronic effects, one would expect the mass of T determined above to be about 80×10^{-6} a.m.u. too small rather than only 14×10^{-6} a.m.u. as was found.

The reason for this discrepancy is as yet unknown. Further measurements are planned which should give additional information and which may improve our understanding of electronic effects on the values of rotational constants.

It should be mentioned that reaction of the TI with the walls of the wave guide was quite troublesome. The absorption intensity never exceeded 1/3 of that predicted because of wall absorption and dissociation. Since only 100 micrograms of tritium were available, the walls could not be presaturated with the chemical. For a period of several hours after all the tritium iodide in the sample bottle was used, the absorption line kept reappearing after the guide was pumped out with as great an intensity as when fresh sample was being added.

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1. Klein and Nethercot, Phys. Rev. 91, 1018, (1953).
2. Burrus and Gordy, Phys. Rev. 92, 1437 (1953).
3. Boyd and Thompson, Spectrochimica Acta 5, 308 (1952).
4. Li, Whaley, and Lauritsen, Phys. Rev. 83, 512 (1951).
5. Microwave Spectroscopy, Schawlow and Townes, Ch. VIII (in press).

H. Magnetic Resonance at Millimeter Wavelengths

(F. M. Johnson and A. H. Nethercot, Jr.)

Observations on the absorption lines of $NiK_2(SO_4)_2 \cdot 6H_2O$ near 2.5 mm wavelength as a function of temperature, angle, and frequency are continuing.

I. Superconductive Surface Resistance at Millimeter Wavelengths

(R. Kaplan and A. H. Nethercot, Jr.)

The first run with the cryostat was not successful. Shorts in the lead wires to the resistance thermometer developed and the temperature could not be read reliably. However it was ascertained that the experimental space could be cooled to 1.7° K by pumping on the helium and that the helium from one transfer lasted about 90 minutes. Three transfers were obtained from a ten liter storage dewar. The heat leak was much larger than was expected from calculations.

The cryostat was disassembled and the faulty lead wires replaced. A few improvements were also made in the microwave power monitor.

The second run was not much more successful. The heat leak to the helium was even larger and the helium lasted only 60 minutes per transfer for unknown reasons.. Only two transfers were made from the ten liter storage dewar because of an accidental plugging of the transfer tube with solid air or ice. In addition, the vacuum space surrounding the tin sample developed a leak toward the end of the run.

The only real data taken were on the absorption of the 12.5 mm radiation by the sample at about 8° K (non-superconducting). These data have not yet been reduced to percentage absorption, but should give an important check on the techniques employed.

V. ELECTRONIC APPARATUS AND TECHNIQUES

Klystron Pulsing Unit

(A. W. Costello and H. Lashinsky)

The klystron pulsing unit mentioned in the previous progress report[1] is essentially completed. The unit consists of a triggered flip-flop employing 3E29 tubes, which is triggered by pulses derived from a signal generator. Great care has been taken in the design of the trigger circuits to avoid any time jitter between successive triggering pulses.

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1. CRL Quarterly Report, April 30, 1954, p. 25.

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